information

distribution ~~information~~, and a recognition/judgment computer 30 for detecting three-dimensional positions of roads and solid objects at high speeds based on the distance information inputted from the image processor 20, for identifying a preceding vehicle or an obstacle based on the result of the detection and for judging whether or not an alarm should be issued to avoid a collision with the preceding vehicle or the obstacle.

The recognition/judgment computer 30 is connected with sensors such as a vehicle speed sensor 4, a steering angle sensor 5 and the like in order to detect a present traveling condition of the vehicle and also it is connected with a display 9 provided at the front of a vehicle driver for informing hazard. Further, the computer 30 is connected with an external interface for example for controlling actuators (not shown) which operate so as automatically to avoid a collision with the obstacle or the vehicle traveling ahead.

The stereoscopic optical system 10 is composed of a pair of left and right CCD (Charge Coupled Device) cameras 10a, 10b. A pair of stereoscopic images taken by the CCD cameras 10a, 10b are processed in the image processor 20 according to the principle of triangulation to obtain three-dimensional distance distribution over an entire image.

The recognition/judgment computer 30 reads the distance distribution information from the image processor 20 to detect three-dimensional positions with respect to the configuration of roads and solid objects such as vehicles and obstacles at high speeds and judges a possibility of collision or contact with these detected objects based on the traveling

detected

condition ~~detected by~~ the vehicle speed sensor 4 and the steering angle sensor 5 of the self vehicle to inform the vehicle driver of the result of the judgment through the display 9.

Fig. 2 shows a constitution of the image processor 20 and the recognition/judgment computer 30. The image processor 20 comprises a distance detecting circuit 20a for producing distance distribution information and a distance image memory 20b for memorizing this distance distribution information. More specifically, the distance detecting circuit 20a calculates a distance to a given object by selecting a small region imaging an identical portion of the object from the left and right stereoscopic images taken by the CCD cameras 10a, 10b, respectively and then obtaining a deviation between these two small regions and outputs in the form of three-dimensional distance distribution information.

Fig. 9 shows an example of either of images taken by the left and right CCD cameras 10a, 10b. When this image is processed by the distance detecting circuit 20a, the distance distribution information outputted from the distance detecting circuit 20a is expressed as a distance image as shown in Fig. 10.

The example of the distance image shown in Fig. 10 has a picture size composed of 600 (laterally) x 200 (longitudinally) picture elements. The distance data are included in white dotted portions that correspond to the portions having a large difference of brightness between two adjacent picture elements aligned in the left and right direction respectively in the image shown in Fig. 9. Further, in this example, the distance detecting circuit

20a treats the distance image as an image composed of 150 (laterally) x 50 (longitudinally) blocks, i.e., 4 x 4 picture elements for one block or one small region. The calculation of distance is performed for each block of the left and right images.

The recognition/judgment computer 30 comprises a microprocessor 30a primarily for detecting the road configuration, a microprocessor 30b primarily for detecting solid objects based on the configuration of a road detected and a microprocessor 30c primarily for identifying a preceding vehicle or an obstacle based on the positional information of the detected solid objects and for judging a possibility of collision or contact with the preceding vehicle or the obstacle and these microprocessors 30a, 30b, 30c are connected in parallel with each other through a system bus 31.

The system bus 31 is connected with an interface circuit 32 to which the distance image is inputted from the distance image memory 20b, a ROM 33 for storing a control program, a RAM 34 for memorizing miscellaneous parameters produced during calculations, an output memory 35 for memorizing the result of processing, a display controller 30d for controlling the display 9 and an I/O interface circuit 37 to which signals are inputted from the vehicle speed sensor 4 and the steering angle sensor 5.

As shown in Fig. 9, the distance image has a coordinate system composed of a lateral axis i, a longitudinal axis j and a vertical axis dp with an origin of the coordinates placed at the left below corner of the distance image. The vertical axis dp indicates a distance to an object which corresponds to the

Strip The

final ~~strip~~ the program goes from S128 to S130 where it is investigated whether or not the process reaches the final group. When the process does not yet reach the final group, the data of the next group are read and hereinafter the same processes are carried out repeatedly. When the process reaches the final group, the division of the groups is completed and the program goes from S130 to S132.

The following steps S132 to S137 are of processes in which further classifications of "side wall" or "object" are carried out to raise the accuracy of the classification performed at S127. After the data of the first group are read at S132, at S133 approximate straight lines are obtained from the positions (Xi, Zi) within the group according to the Hough transformation or the linear square method to calculate a gradient overall the group.

Then, the program goes to S134 where the group is reorganized such that the group having a gradient inclined toward X-axis is classified into the "object" group and the group having a gradient inclined toward Z-axis is classified into the "side wall" group. Further, at S135, miscellaneous parameters of the group are calculated. With respect to the group classified "object", these parameters include an average distance which is calculated from the distance data within the group, X-coordinates at the left and right ends of the group and the like and with respect to the group classified "side wall", those parameters include an arrangement direction of the data (gradient with respect to Z-axis), Z, X coordinates of the front and rear ends of the group and the like. In this embodiment, in order to raise

position and the X-coordinates thereof are determined according to the procedure which will be described hereinafter.

At S202, a node N_s corresponding to an end point on the vehicle side of the selected side wall group is established based on the Z-coordinate of the end point and the X-coordinate of the node N_s is established being adjusted to the X-coordinate of the end point. Next, the program goes to S203 where the next node N_{s+1} is established in the direction of the gradient of the side wall group. Next, when the node N_{s+i} ($i \geq 2$) is determined, its direction is established along a direction of the second previous node.

Then, the program goes to S204 where, as shown in Fig. 15, the position of the wall surface is searched by a so-called "pattern matching" within a specified searching range to extract a solid object P_i for every strip within the searching range. For example, the searching range in the X-axis direction has ± 3 to 5 meters in the X-axis direction and ± 1 meter in the Y-axis direction with its center placed at a coordinate (X_{ns+i}, Z_{ns+i}) of the node N_{s+i} established at S203.

The matching of the wall surface pattern is performed to the solid object P_i within the searching range. Fig. 16 shows an example of the wall surface pattern (weight coefficient pattern) used for the pattern matching. The wall surface pattern shown in Fig. 16 is a pattern for the wall surface on the left side and a symmetric pattern to this pattern is used for the wall surface on the right side. The lateral axis of this wall surface pattern coincides with the distance in the X-axis direction and the longitudinal axis indicates a weight coefficient. A maximum

on the right ~~side~~. In the example shown in Fig. 14, the wall surface from the 9th node to the 26th node is detected on the right side of the self vehicle and the 9th node is denoted as the start point N_s and the 26th node is denoted as the end point N_e. These nodes are used for later processes as effective nodes.

Thus processed position of the wall surface is further corrected by a program shown in Fig. 7 and Fig. 8 using new data obtained from programs shown in Fig. 3 through Fig. 5.

The programs shown in Fig. 7 and Fig. 8 is a program for correcting the wall surface. At S301, it is investigated whether or not the start point N_s of the effective nodes is larger than the first node N_1 of the wall surface model. When $N_s = N_1$, the wall surface has been already detected up to the first node N_1, the program skips to S306. When $N_s > N_1$, the program goes to S302 where the previous node N_{s-i} (i = 1, 2, 3 etc.) is established. Then, at S303 the wall surface pattern is searched and at S304 the X-coordinate of the wall surface is determined based on the result of searching.

Next, the program goes from S304 to S305 where it is investigated whether or not the process has reached the first node. If not yet reached the first node N_1, the steps S302 to S304 are repeated to continue the searching of the wall surface position up to the node N_1. When the processes up to the first node N_1 are finished, the program goes to S306 where it is checked whether or not the end point N_e of the effective nodes is smaller than the last node N_{se} of the wall surface model (for example, node N_{41} in case of the wall surface model constituted of 41 nodes).

As a result of this, when $N_e = N_{se}$, that is, the wall

surface has ~~been~~ already detected up to the last node, the program skips from S306 to S311. When $N_e < N_{se}$, the program goes from S306 to S307 where the node N_{e+1} after the end point N_e is successively established and further at S308 the pattern matching of the wall surface is performed. According to the result of the pattern matching, at S309 the X-coordinate of the wall surface is determined and then at S310 it is checked whether or not the process has reached the last node N_{se}. The matching of the wall surface position is continued until the last node N_{se} and when the processes up to the last N_{se} is finished, the program goes to S311.

These processes of establishing the nodes, the matching of the wall surface pattern and the determination of the X-coordinate at the steps S302 to S304 and the steps S307 to S309, are the same as the processes at the steps S203, 204 and S205 in the aforementioned program of the wall surface detecting process.

The processes after S311 are for correcting the position (X-coordinate) of respective nodes from the first node N_1 to the last node N_{se}. First, at S311 the data of the first node N_1 is set and the program goes to S312. The processes from S312 to S321 are repeatedly carried out by successively setting the data of the next node.

At S312, the wall surface at the node N_i is searched and at S313 it is checked whether or not the wall surface is detected by the pattern matching. If it is judged that the wall surface is detected, the program goes from S313 to S314 where it is investigated whether or not the difference between the position X_{pw} of the wall surface and the position X_{ni} of the node